SIGNALCOM CANADA CORPORATION

Transport Canada Report No. TP-10218E

RAILWAY SIGNAL ENFORCEMENT SYSTEM PHASE I DEVELOPMENT

Volume I - Main Report

prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

by

John E. Warner
Robert W. Tiernay

February 1990

6 Indell Lane, Brampton, Ontario, Canada L6T 3Y3 Phone: (416) 791-9550 Telex: 06-988595

Transport Canada Report No. TP-10218E

CA1
DTC800-
90
R17
v.
1

41.D

451924

RAILWAY SIGNAL ENFORCEMENT SYSTEM PHASE I DEVELOPMENT

Volume 1 - Main Report

prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

by

John E. Warner
Robert W. Tiernay

Library and Information Centre / Centre de Documentation (GSLA)
RECEIVED - REÇU LE
JUL 11 1990
Transport Canada / Transports Canada

Signalcom Canada Corporation
6 Indell Lane
Brampton, Ontario
L6T 3Y3

February 1990

451924

CA 441757

91-02519/

DISCLAIMER

The contents of this report reflect the view of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada

Un sommaire en français de ce rapport est inclus avant la Table des matières.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 10218E	7011	

4. Title and Subtitle

RAILWAY SIGNAL ENFORCEMENT SYSTEM
PHASE I DEVELOPMENT
Volume I - Main Report

5. Publication Date

February 1990

6. Performing Organization Document No.

7. Author(s)

John E. Warner, Robert W. Tiernay

8. Transport Canada File No.

D1465-520

9. Performing Organization Name and Address

Signalcom Canada Corporation
6 Indell Lane
Brampton, Ontario L6T 3Y3

10. DSS File No.

095E.T8200-7-7544

11. DSS or Transport Canada Contract No.

T8200-7-7544/01-SE

12. Sponsoring Agency Name and Address

Transportation Development Centre (TDC)
200 René Lévesque Blvd West
West Tower, Suite 601
Montreal, Quebec H2Z 1X4

13. Type of Publication and Period Covered

Final Report

14. Project Officer

W.G. Rowan

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Volumes II, III and IV contain appendices to this report which are not releasable.

16. Abstract

This report describes a system designed for signal enforcement on existing Centralized Train Control (CTC) territory by means of radio data communication. The primary objective was to develop a system that would enforce, in a vital manner, the speed and authority limits of the existing wayside signal system and to evaluate the system's performance over a six month testing period. In this system, locomotives would interrogate approaching signal locations via data radio. The aspect information would then be automatically enforced by the on-board equipment. This first phase of development did not reach the field test stage. The system requires three major components: a wayside interface to the existing signal towers to monitor signal aspects, a communications system to enable approaching locomotives to access this information, and onboard equipment to allow the locomotive to determine its position, evaluate its status in conforming to the signals and apply the train brakes if necessary. The wayside component of the system was fully developed and tested, and the onboard hardware was developed. However, the onboard software was not completed and the onboard hardware was not fully tested. The present status of the hardware and software is fully documented to permit ongoing development.

17. Key Words	18. Distribution Statement
ATCS, Railway signal enforcement, Microprocessor control, Data communications	Limited number of copies of Volume I only are available on request from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
unclassified	unclassified	—	20+app.	—

TDC/CDT 79-005
Rev 86

Canada

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada	2. N° de l'étude	3. N° de catalogue du destinataire
TP 10218E	7011	

4. Titre et sous-titre

RAILWAY SIGNAL ENFORCEMENT SYSTEM
PHASE I DEVELOPMENT
Volume I - Main Report

5. Date de la publication

février 1990

6. N° du document de l'organisme exécutant

7. Auteur(s)

John E. Warner, Robert W. Tiernay

8. N° de dossier — Transports Canada

D1465-520

9. Nom et adresse de l'organisme exécutant

Signalcom Canada Corporation
6 Indell Lane
Bramption (Ontario) L6T 3Y3

10. N° de dossier — ASC

095E.T8200-7-7544

11. N° de contrat — ASC ou Transports Canada

T8200-7-7544/01-SE

12. Nom et adresse de l'organisme parrain

Centre de développement des transports (CDT)
200 ouest, boul. René-Lévesque
Tour ouest, suite 601
Montréal (Québec) H2Z 1X4

13. Genre de publication et période visée

final

14. Agent de projet

W.G. Rowan

15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)

Les volumes II, III et IV renferment des appendices qui ne peuvent être mises en circulation.

16. Résumé

La recherche concerne un système destiné à assurer une surveillance continue des trains, en circulation dans les territoires à commande centralisée de la circulation, et ce par une liaison radio sol-trains. La recherche a eu pour objet principal d'étudier un système capable de gérer et, au besoin, d'exécuter automatiquement les consignes de vitesse et de distance indiquées par la signalisation latérale puis d'évaluer les performances de ce système durant une période d'essais de six mois. Il est proposé d'équiper les unités de signalisation latérale d'une unité d'interface que les locomotives pourront interroger de loin par liaison radio. Si le conducteur n'obéit pas correctement aux indications de la signalisation, une logique embarquée se chargera d'intervenir automatiquement. Cette recherche n'a pas atteint l'étape des essais sur le terrain. Le système proposé comporte trois éléments essentiels : une unité d'interface sur les appareils de signalisation latérale, une liaison radio sol-trains et un équipement informatique embarqué permettant de localiser la locomotive, d'en évaluer la situation par rapport aux consignes reçues et, le cas échéant, d'effecteur un freinage d'urgence. L'unité d'interface au sol a été mise au point et éprouvée et l'équipement informatique embarqué a également été mis au point. Mais la mise au point du logiciel correspondant n'est pas terminée et tous les essais de l'équipement informatique embarqué n'ont pas encore en lieu. L'état actuel de développement de l'équipement et du logiciel informatique est dûment documenté afin de permettre la poursuite des travaux.

17. Mots clés	18. Diffusion
SACT, surveillance de la conduite des trains, contrôle informatisé	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
non classifiée	non classifiée	—	20+app.	—

CDT/TDC 79-005
Rev 88

Canada

EXECUTIVE SUMMARY

The Hinton, Alberta collision of February 1986 has prompted investigation of means to enforce compliance of train movement authorities. Attention has been focused on the use of Advanced Train Control Systems (ATCS) technology for this purpose. The protection offered by ATCS may not be as complete as that currently available via conventional signalling if track integrity options are not provided. Also, the realization of full ATCS development may be several years away.

In response to the above, Signalcom Canada Corporation proposed a system which merges an Advanced Train Control System (ATCS) and current wayside signalling technologies. In this system, locomotives were to interrogate approaching signal locations via data radio. The aspect information was then to be automatically enforced by the on-board equipment.

The primary objective was to develop a system that would enforce, in a vital manner, the speed and authority limits of the existing wayside signal system and to evaluate the system's performance over a six-month testing period. This first phase of development did not reach the field test stage. The wayside component of the system was fully developed and tested, and the on-board hardware was developed. However, the on-board software was not completed and the on-board hardware was not fully tested.

SYSTEM DESCRIPTION

One full-duplex channel is required for data radio communications. The two frequencies used are transposed at every wayside location. Locomotives approaching a given wayside site share the same frequency allocation. Those messages reporting signal states from the wayside interface unit (WIU) to locomotives are considered vital. The ATCS radio frequency communication protocol is used to transfer data in both directions. When entering a new block (as detected by a start of block transponder or oedometer reading) the on-board computer will wake the next wayside WIU and thus cause it to report the state of all signals 64 times at a mean reporting interval of 3 seconds.

When an aspect is received on board, the locomotive's speed and location are compared to maximum zone speed and braking profile (if appropriate). This information will be displayed and braking will be automatically enforced via a full-service brake application if the on-board computer determines that an unsafe situation exists. The LOBC interfaces to a transponder interrogator and axle generator to determine position. It contains a two-channel half-duplex UHF radio and data modem to communicate with the WIU. The Locomotive On-Board Computer (LOBC) performs both vital and non-vital operations. Processing is performed by two VME 68000 CPUs.

DEVELOPMENT STATUS

Ten signal locations on the Halton Sub were to be equipped with a WIU and approximately 50 transponders were installed between Silver and Tansley. The WIU monitors all signals associated with a particular wayside location using the vital inputs. The WIU contains vital subsystems the same as used in Microlok.

Hardware is available to equip a locomotive but one of the boards has had only limited testing. Also, the software development for the LOBC is incomplete. The man-machine interface (MMI) for the on-board computer consists of a 2 * 20 character display and is complete. The development status is summarized below.

	Hardware	Software	Testing
MMI	Complete	Complete	Subsystem Level
WIU	Complete	Complete	Subsystem Level
LOBC	Complete	Incomplete	none

SOMMAIRE

L'accident ferroviaire qui a eu lieu en février 1986 à Hinton (Alberta) a été à l'origine d'une enquête sur les moyens permettant d'assurer une surveillance continue des trains en circulation. Un des moyens étudiés a été la mise en oeuvre du système avancé de commande des trains (SACT). Or, ce système ne garantit pas une protection aussi étendue que celle assurée par les systèmes actuels de signalisation classique, à moins d'opter en plus pour des circuits de voie. En outre, la mise en oeuvre du SACT ne sera achevée que dans plusieurs années.

Devant cet état de choses, la Signalcom Canada Corporation a proposé un procédé qui allie la technologie du SACT à celle de la signalisation latérale actuelle. Elle propose d'équiper les appareils de signalisation latérale d'une unité d'interface que les locomotives pourront interroger de loin par liaison radio et qui répondra en donnant des indications sur le signal affiché. Si le conducteur n'obéit pas correctemant à celui-ci, une logique embarquée se chargera d'intervenir automatiquement.

La présente recherche a eu pour objet d'étudier un système capable de gérer et, au besoin, d'exécuter automatiquement les consignes essentielles de vitesse et de distance indiquées par la signalisation latérale, puis d'évaluer les performances de ce système durant une période d'essais de six mois. Cette recherche n'a pas atteint l'étape des essais sur le terrain. Les unités d'interface en bordure de voie ont été mises au point et éprouvées et le matériel informatique embarqué a également été mis au point. Mais le logiciel correspondant n'est pas encore au point et tous les essais du matériel embarqué n'ont pas encore eu lieu.

DESCRIPTION

La liaison sol-trains est exploitée en mode duplex, le système émettant sur deux fréquences alternées. La locomotive et l'unité d'interface en aval utilisent les mêmes fréquences allouées. Les signaux émis par l'unité d'interface et destinés à la locomotive portent des indications essentielles sur la signalisation. Le protocole de communications radio du SACT sert à transmettre les données dans les deux sens. Lorsqu'un train entre dans un canton, le transpondeur du canton ou l'odomètre de bord envoie un signal à l'ordinateur embarqué qui alterte l'unité d'interface la plus proche en aval. Celle-ci émet alors un signal indiquant l'état de la signalisation, 64 fois, à un intervalle moyen de 3 secondes.

À la réception du signal, l'ordinateur embarqué compare les paramètres vitesse et position de la locomotive à la consigne de vitesse maximale et, le cas échéant, au profil de freinage prévu pour le canton considéré. Cette information s'affiche aussi en cabine. Si le conducteur n'obéit pas correctement aux consignes affichées, l'ordinateur déclenche automatiquement le freinage d'urgence. La position du train est repérée grâce à des transpondeurs en bordure de voie et à un odomètre de bord alimenté par un générateur d'impulsions sur essieu. L'ordinateur de bord commande une liaison radio deux voies fonctionnant dans la bande UHF et exploitée en mode semi-duplex, ainsi qu'un modem pour la réception des données provenant de l'unité d'interface. L'ordinateur embarqué gère des fonctions tant essentielles que non essentielles, tandis que deux unités centrales de traitement VME 68000 assurent le traitement de l'information.

ÉTAT DE LA RECHERCHE

Dix appareils de signalisation latérale devaient être équipés d'une unité d'interface dans la subdivision Halton et une cinquantaine de transpondeurs posés en voie entre Silver et Tansley. L'unité d'interface gère tous les signaux porteurs d'indications essentielles liés à la zone placée sous sa gestion. De plus, elle renferme les mêmes sous-systèmes vitaux que ceux du système Microlok.

Bien que le matériel informatique embarqué soit disponible, une des cartes nécessaires n'a pas encore été éprouvée à fond. La mise au point du logiciel correspondant n'est pas encore terminée. L'interface homme-machine de bord comprend un visuel 2 fois 20 caractères; sa mise au point est chose faite. Ci-dessous figure un tableau récapitulant l'état de la recherche :

	Matériel	Logiciel	Essais
Interface homme-machine	Terminé	Terminé	Niveau des sous-systèmes
Unité d'interface	Terminé	Terminé	Niveau des sous-systèmes
Ordinateur embarqué	Terminé	En cours	Aucun

TABLE OF CONTENTS

1. INTRODUCTION 1
   1.1 GENERAL 1

2. SYSTEM OBJECTIVES 1
   2.1 PRIMARY OBJECTIVE 1
   2.2 SECONDARY OBJECTIVES 1

3. PROJECT STATUS 2

4. SYSTEM DESCRIPTION 2

5. LOCOMOTIVE AND WAYSIDE EQUIPMENT OVERVIEW 5
   5.1 ORIGINAL DESIGN 5
      5.1.1 Locomotive Hardware 5
      5.1.2 Wayside Hardware 5
      5.1.3 ATCS Mobile Communications Package (MCP) Hardware 6
      5.1.4 Software 6
   5.2 REVISED DESIGN 6
      5.2.1 Locomotive Hardware 6
      5.2.2 Wayside Hardware 6
      5.2.3 ATCS MCP Hardware 6
      5.2.4 Software 6

6. DETAILED DESCRIPTION - HARDWARE 7
   6.1 ORIGINAL LOCOMOTIVE HARDWARE 7
      6.1.1 General 7
      6.1.2 Interface Descriptions 9
      6.1.3 MMI 9
   6.2 ORIGINAL WAYSIDE HARDWARE 10
      6.2.1 General 10
      6.2.2 Transponder Locations 10
      6.2.3 WIU 10
         6.2.3.1 WIU Functions 12
      6.2.4 LPU Functions 12
      6.2.5 Battery Surge Protector 12
   6.3 REVISED LOCOMOTIVE HARDWARE DESIGN 13
      6.3.1 General 13
      6.3.2 Interface Design 13
      6.3.3 MMI 13

6.4 REVISED WAYSIDE HARDWARE 13
6.4.1 General 13
6.4.2 Transponder Locations 13
6.4.3 WIU 13
6.4.3.1 WIU Functions 14
6.4.4 LPU Functions 14
6.4.5 Battery Surge Protector 14

7. DETAILED DESCRIPTION - SOFTWARE 15
7.1 ORIGINAL DESIGN DESCRIPTION 15
7.1.1 Communication Software 15
7.1.2 Safety Platform 16
7.1.3 WIU 16
7.1.4 LOBC 16
7.2 REVISED SOFTWARE 16
7.2.1 Communication System 16
7.2.2 Safety Platform 17
7.2.3 WIU 17
7.2.4 LOBC 17

8. DEVELOPMENT STATUS 18
8.1 SYSTEM DESIGN 18
8.2 SUBSYSTEM STATUS 18
8.3 PACKAGING 18
8.4 HARDWARE 19
8.5 SOFTWARE 19

9. PROJECT CONTINUATION 20

10. CONCLUSIONS 20

APPENDICES (PROTECTED)

Volume II: A. THE VME-VLS SYSTEM
B. RADIO HARDWARE
C. MISCELLANEOUS BOARDS
D. VITAL BRAKE CONTROL CIRCUIT SAFETY ANALYSIS

Volume III: E. DRAWINGS

Volume IV: F. COMMUNICATION SYSTEM
G. WAYSIDE INTERFACE UNIT SOFTWARE DESIGN DOCUMENTATION
H. CN SIGNAL ENFORCEMENT, LOBC SOFTWARE, OVERVIEW
I. MAN-MACHINE INTERFACE UNIT

GLOSSARY

ATCS	Advanced Train Control System
bps	bits per second
CMOS	Complementary Metal Oxide Silicon
CN	Canadian National
CPU	Central Processor Unit
CRC	Cyclic Redundancy Code
CRC_{16}	16 bit CRC
CTC	Centralized Traffic Control
EMI	Electro-Magnetic Interference
GFSK	Gaussian Frequency Shift Keying
I/O	Input/Output
K	Kilo
KHz	Kilo-Hertz
LOBC	Locomotive On-Board Computer
LPU	Lightning Protection Unit
MCP	Mobile Communications Package
MHz	Mega-Hertz
MITAP	Mobile Information Terminal And Processor
MMI	Man Machine Interface
MS-DOS	MicroSoft Disk Operating System
PC	Personal Computer
PC-AT	80286 based Personal Computer
PTxD	Primary Text Display
RF	Radio Frequency
SCC	Signalcom Canada Corporation
TBD	To Be Decided
UHF	Ultra High Frequency
VDC	Volts Direct Current
VLS	Vital Low Speed
WIU	Wayside Interface Unit

1. INTRODUCTION

1.1 GENERAL

The Hinton collision of February 1986 has prompted investigation of means to enforce compliance of train movement authorities. Attention has been focused on the use of Advanced Train Control Systems (ATCS) technology for this purpose. The use of ATCS technology has some limitations. An ATCS interface to existing wayside signalling systems in Centralized Train Control (CTC) territory has not as yet been defined in detail. The realization of this interface in the ATCS development schedule may be several years away. In addition, the protection offered by ATCS may not be as complete as that currently available via conventional signalling if track integrity options are not provided. In response to the above, Signalcom Canada Corporation (SCC) proposed a system which merges ATCS and current wayside signalling technologies. In this system, locomotives were to interrogate approaching signal locations via data radio. The aspect information was then to be automatically enforced by the on-board equipment.

2. SYSTEM OBJECTIVES

2.1 PRIMARY OBJECTIVE

The primary objective was to develop a system that would enforce, in a vital manner, the speed and authority limits of the existing wayside signal system and to evaluate the system's performance over a six-month testing period.

2.2 SECONDARY OBJECTIVES

Secondary objectives were to:

- implement and test ATCS communications software (Levels 1 through 7).
- implement and test current ATCS-specific locomotive hardware components: transponders, and UHF 4800 bps GFSK data radio.
- develop a safe cost-effective means of interfacing to existing wayside equipment.
- implement and test a general braking algorithm.
- develop ergonomic human interfaces for both wayside and on-board applications.

3. PROJECT STATUS

All development work on this signal system stopped in late 1989. At the time that Signalcom terminated work on the system, several of the secondary objectives had been achieved.

These objectives included a subset of the ATCS communication software with operational limitations, an implementation of the wayside equipment, and assembly of the on-board package.

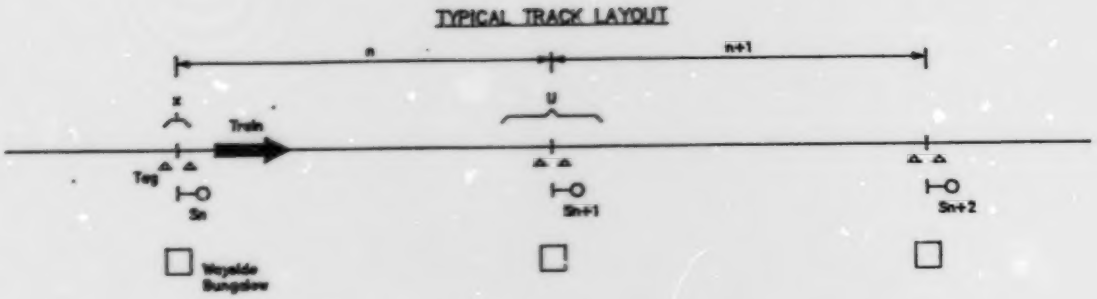
4. SYSTEM DESCRIPTION

Each transponder was programmed in binary with a road ID, sequence number and CRC protection. The transponder number is used to index an on-board data base which contains location, wayside WIU addresses, zone speed, grade and channel frequency information.

One full-duplex channel is required for data radio communications. The two frequencies used are transposed at every wayside location. Locomotives approaching a given wayside site share the same frequency allocation. Those messages reporting signal states from the WIU to locomotives are considered vital. The ATCS RF communication protocol is used to transfer data in both directions. When entering a new block (as detected by a start of block transponder or oedometer reading) the on-board computer will wake the next wayside WIU and thus cause it to report the state of all signals 64 times at a mean reporting interval of 3 seconds. The message from the WIU contains the number of reporting times left. Other locomotives approaching that particular wayside unit can use the signal information and wake up the wayside unit if the counter expires.

When an aspect is received on board, the locomotive's speed and location are compared to maximum zone speed and braking profile (if appropriate). This information will be displayed and braking will be automatically enforced via a full-service brake application if the on-board computer determines that an unsafe situation exists. Until such time that a detailed operational and safety review is completed, braking will not be enforced. Instead, a light installed in the MMI (driven from the LOBC on a separate metallic pair) is to be used as an indication that the brakes would have been applied.

Refer to Figure 1 for a state diagram of the system operation.


TYPICAL TRACK LAYOUT
n
n+1
x
U
Train
Tag
Sn
Sn+1
Sn+2
Wayside Bungalow

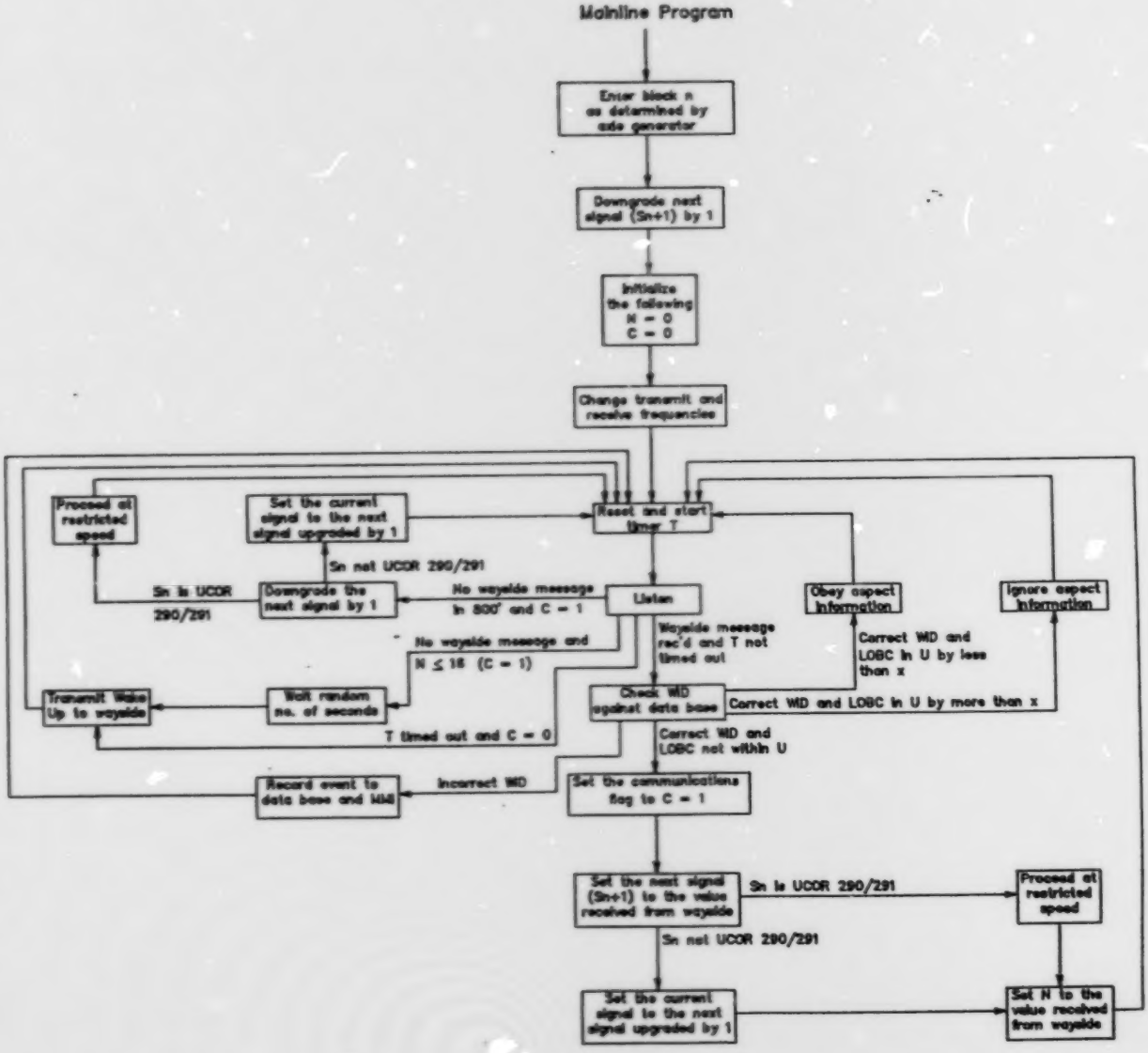

Mainline Program
Enter block n as determined by axle generator
Downgrade next signal (Sn+1) by 1
Initialize the following N = 0 C = 0
Change transmit and receive frequencies
Proceed at restricted speed
Set the current signal to the next signal upgraded by 1
Reset and start timer T
Sn not UCOR 290/291
Sn is UCOR 290/291
Downgrade the next signal by 1
No wayside message in 800' and C = 1
Listen
Obey aspect information
Ignore aspect information
Wayside message rec'd and T not timed out
Correct WD and LOBC in U by less than x
No wayside message and N ≤ 18 (C = 1)
Transmit Wake Up to wayside
Wait random no. of seconds
Check WD against data base
Correct WD and LOBC in U by more than x
T timed out and C = 0
Correct WD and LOBC not within U
Record event to data base and MMI
Incorrect WD
Set the communications flag to C = 1
Set the next signal (Sn+1) to the value received from wayside
Sn is UCOR 290/291
Proceed at restricted speed
Sn not UCOR 290/291
Set the current signal to the next signal upgraded by 1
Set N to the value received from wayside

Figure 1

ABBREVIATIONS

n	Represents the current block that the LOBC occupies
n+1	Represents the next block that the LOBC will occupy
U	Zone of uncertainty due to error in axle generator
Sn	Signal for the current block
Sn+1	Signal for the next block
N	No. of wayside transmissions left (maximum of 64)
C	Equal to 1 if communications established in the current block
T	Timer used to determine time since last wayside message received
WID	Wayside Interface Unit(WIU) identification number
UCOR 290	Proceed at restricted speed
UCOR 291	Stop and proceed at restricted speed
x	Distance between the End of Block and Start of Block tags
MMI	Man-Machine Interface

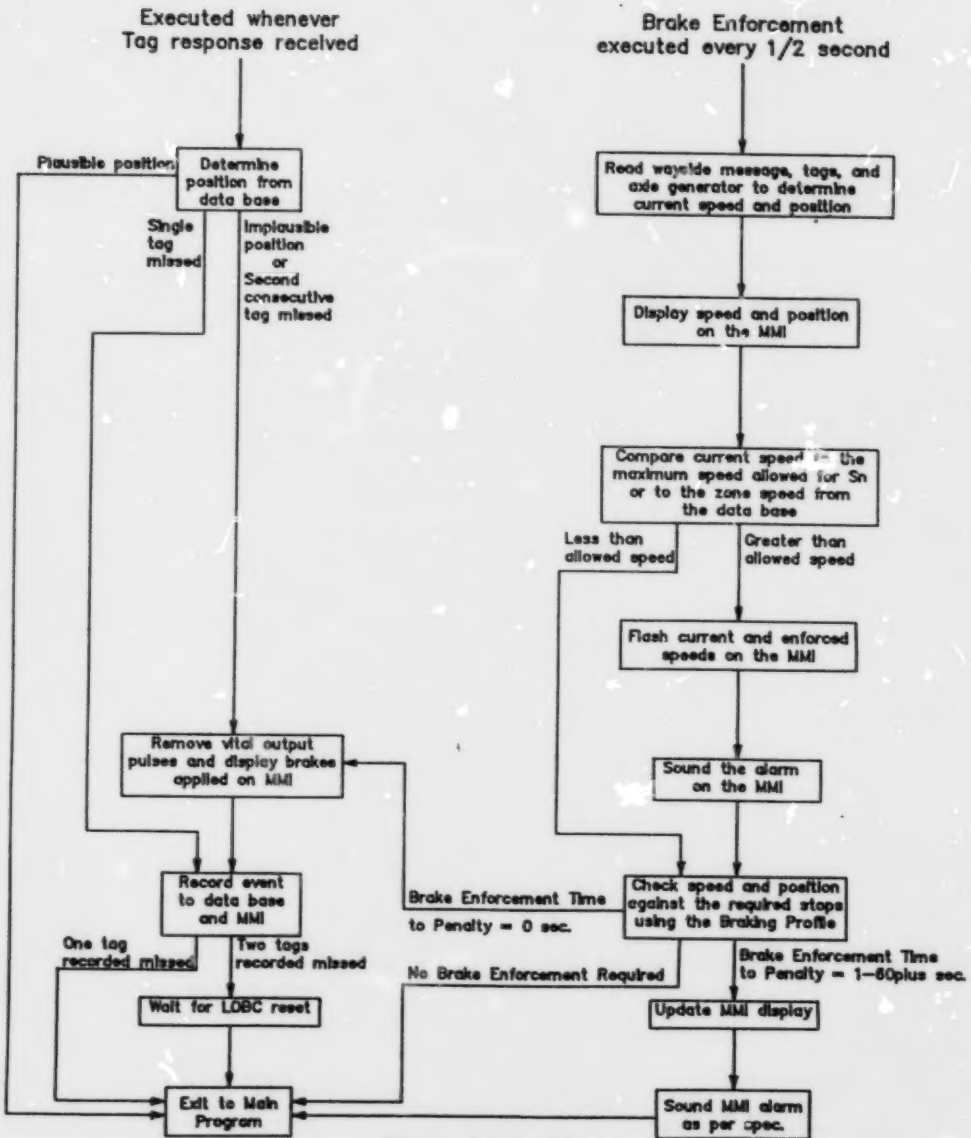

Executed whenever
Tag response received
Brake Enforcement
executed every 1/2 second
Plausible position
Determine position from data base
Single tag missed
Implausible position or Second consecutive tag missed
Read wayside message, tags, and axle generator to determine current speed and position
Display speed and position on the MMI
Compare current speed to the maximum speed allowed for Sn or to the zone speed from the data base
Less than allowed speed
Greater than allowed speed
Flash current and enforced speeds on the MMI
Remove vital output pulses and display brakes applied on MMI
Sound the alarm on the MMI
Record event to data base and MMI
Brake Enforcement Time to Penalty = 0 sec.
Check speed and position against the required stops using the Braking Profile
One tag recorded missed
Two tags recorded missed
No Brake Enforcement Required
Brake Enforcement Time to Penalty = 1-60plus sec.
Wait for LOBC reset
Update MMI display
Exit to Main Program
Sound MMI alarm as per spec.

Figure 1 (cont'd)

5. LOCOMOTIVE AND WAYSIDE EQUIPMENT OVERVIEW

The on-board and wayside package designs were modified during the execution of the project to reduce technological risk and engineering effort. These changes did not effect the original system definition. This section outlines both the original and revised on-board and wayside designs.

5.1 ORIGINAL DESIGN

5.1.1 Locomotive Hardware

Two locomotives were to be equipped with:

- an ATCS reader (DSL);
- an LOBC (Locomotive On-Board Computer)-interface to the interrogator, penalty brake system and axle generator. The LOBC contains a two channel half-duplex UHF radio and data modem. The LOBC performs both vital and non-vital operations. Processing is performed by two VME 68000 CPUs;
- a Man-Machine Interface Unit (MMI);
- an UHF antenna;
- a printer.

5.1.2 Wayside Hardware

Ten signal locations on the Halton Sub were to be equipped with:

- a WIU (Wayside Interface Unit). This unit interfaces to the existing signal system. It contains a low power single channel half-duplex UHF radio to communicate with the locomotive. The WIU contains vital sub-systems. Processing is performed by two VME 68000 CPUs.
- an UHF antenna.

In addition, approximately 50 transponders were installed between Silver and Tansley. Tags were placed at the following locations according to the following general rules:

- to define system boundaries;
- as required for accurate position determination at the beginning and ends of blocks;
- to provide accurate route determination at switch locations.

5.1.3 ATCS Mobile Communications Package (MCP) Hardware

DOC approved ATCS 900 MHz radio/modems were not available when the project was initiated. Technology available at that time was specified instead. A two-channel semi-duplex UHF (approximately 450 Mhz) radio with 25 KHz channel bandwidth was used. The transmit deviation was set so that the transmitted spectrum was the same as per ATCS specifications. The receive channel bandwidth remains at 25 Khz. GFSK transmission at 4800 bps was used. The power level had not been determined. Preliminary investigations indicated that two watts should be sufficient for this application.

A mag-stick UHF antenna is to be provided for the MCP. A grounded vertical antenna is to be provided for the wayside.

5.1.4 Software

The signal enforcement software is divided into four logical groups. These major groups revolved around functions and were: the safety platform, the communication system, the WIU, and the LOBC.

The software design was segmented to facilitate the orderly development of the software. These smaller subsets allowed teams to work on selected areas independently of each other. It also allowed for the maximum re-usage of the software between the LOBC and the WIU.

5.2 REVISED DESIGN

5.2.1 Locomotive Hardware

There was no change in the equipment to be installed on the locomotive.

5.2.2 Wayside Hardware

The WIU was the only component of the wayside to be changed. The dual 68000 VME CPUs were removed and replaced with a single 80188 based CPU running on the VLS bus.

5.2.3 ATCS MCP Hardware

No change.

5.2.4 Software

The revised software eliminated the safety platform software in both the LOBC and the WIU. This allowed the wayside hardware to be reduced a single 80188 CPU. The elimination of the safety platform also simplified the software on the LOBC. With the removal of the safety platform then the requirement for identical tasks running on each CPU was eliminated. Thus the requirement for critical interprocessor communication was abolished

6. DETAILED DESCRIPTION - HARDWARE

6.1 ORIGINAL LOCOMOTIVE HARDWARE

6.1.1 General

Locomotive hardware consists of two components: the LOBC and the MMI. The LOBC was to contain vital subsystems while the MMI is non-vital.

The basic packaging, connectors and power supplies used in the LOBC hardware are illustrated in Figure 2. The LOBC was to be located in the short hood. In the original design the unit was to measure approximately 12"Hx24"Wx12"D.

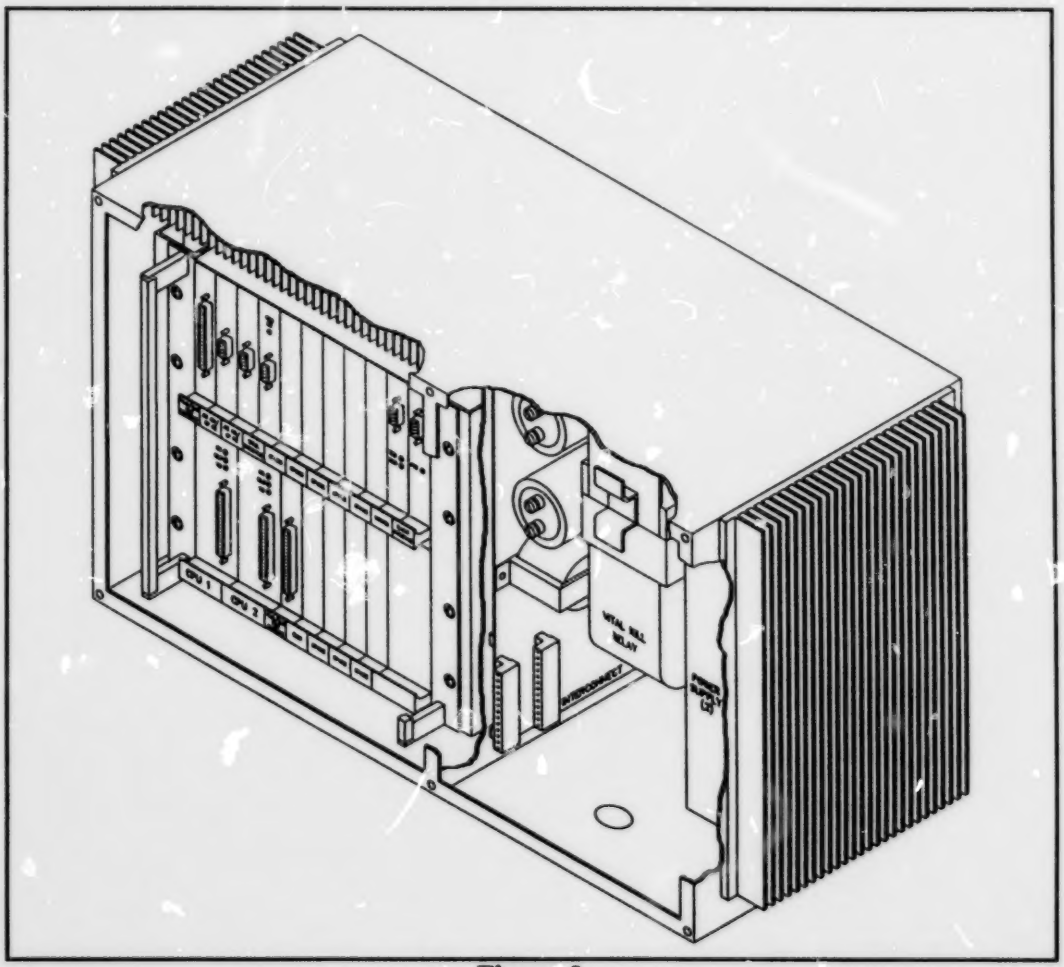


Figure 2

Vitality of the unit was to be achieved by a combination of classical duplication and comparison techniques and self-checking techniques such as used by US&S MicroLok. This design methodology allows for optimal hardware/software cost-trade-off.

The architecture is based on two busses. VME for high-speed processing and a vital low-speed I/O bus (similar to that used in MicroLok). The use of a separate low-speed bus allows for cost-effective vital and non-vital I/O.

The use of CMOS integrated circuits and heat sinks ensures a low internal operating temperature. The unit will operate from -40 to 70 degrees Celsius.

A divider located between the two sides acts as a barrier to EMI and high voltage transients. Transorbs and EMI filter pins are provided on all lines entering the "clean area." The 72-volt locomotive power input is to be conditioned (filtered and transorbed) before it enters the two isolated power supplies.

One power supply is provided for the MITAP and radio (13.6V). The other is for the computer (+5, +/-15 VDC).

The LOBC implements a subset of ATCS LOBC (On-Board Computer) and MCP (Mobile Communications Package) functions. Exact ATCS mechanical packaging specifications were not adhered to.

Card Complement		
2	VME 6800 CPU Cards (each with two serial ports)	
1	Vital Kill Card	to interface to the two CPUs — required a continuous pulse train from both CPUs to prevent brake application
1	Locomotive Interface Card	contains two axle generator interfaces, one BP pressure interface, one reverse handle interface. Two of these cards are required in a live system, each with only one axle generator interface
1	Modem/Sync Detect Card	contains the 4800 bps GFSK modem and ATCS sync detect circuitry
1	Radio Interface Card	contains circuitry to interface to the data radio
1	Bus Interface Card	interfaces from the dual CPUs to the vital low-speed bus

6.1.2 Interface Descriptions

(1) Reader Interface

The LOBC is equipped with an RS-232 interface for the DSL reader as the RS-422 interface specified under ATCS was not available from DSL at the time the equipment was ordered.

(2) Axle Generator Interface

The axle generator is used to determine location between transponders. Two axle generator interfaces circuits will be provided in the LOBC. This allows two separate axles to be instrumented and thus reduces inaccuracy due to slippage. An accuracy of 1% is assumed in the design of the system.

(3) Penalty Brake Interface

The hardware required to interface to the brake system (at the same point the vigilance monitor system connects) consists of a vital relay. The relay releases if a pulse train from either CPU is absent. Thus if either CPU fails or one (or both) decide that a penalty brake application is required, the vital relay releases. The MMI will display LOBC requested brake applications. A light (wired through contacts on the vital relay in the LOBC) is to be installed on the MITAP to allow the visual monitoring of the system. It is envisaged that the system would be rewired (and thus become fully armed) only under the scrutiny of CN's Engineering personnel and then for a limited time period.

(4) Brake Pipe Pressure Interface

As the braking profile will be affected by the pressure in the brake pipe, the pressure is to be monitored by the LOBC.

(5) Reverser Handle Interface

An interface to the reverser lever contacts is required to determine the direction of motion. Without this interface it is not possible to determine the direction of motion — except at transponder locations.

(6) Printer Interface

A small (20 character) printer is provided to log the statistical data generated during testing. The location of the printer has not been determined.

6.1.3 MMI

The MMI is used to display zone speed, braking information and location information. It is planned to use SCC's MITAP (Mobile Information Terminal and Processor) for this function. The MITAP is to be mounted on the locomotive console. The unit measures 4¼"Hx10"Wx9¼"D.

The MITAP is to interface to the LOBC via an RS-232 interface. The MMI will appear as a dumb terminal to the LOBC (VT-100).

6.2 ORIGINAL WAYSIDE HARDWARE

6.2.1 General

The wayside hardware is composed of four components. The WIU and LPU (Lightning Protection Unit) are co-located with the signal relays. The transponders are located near the signals themselves. A battery surge protector will be installed as close as possible to the WIU. The WIU contains vital sub-systems. The WIU and LPU can be 19" rack mounted. The WIU occupies 5" of rack space. The LPU occupies 6" of rack space. Railway industry standard components are used in the design of the WIU and LPU to eliminate the possibility of untried component failure.

6.2.2 Transponder Locations

Transponders were located according to the following basic rules:

(1) two transponders at the entrance point to enforced territory.

(2) two transponders spanning the joint at each signal location.

Table 1 gives the locations of the transponders.

6.2.3 WIU

The WIU is packaged in single-height (3U) format. It can also be packaged in double height format. The basic hardware/software design philosophy was the same as that for the LOBC. The WIU was to use two busses: VME and a low speed vital bus. A field survey conducted by SCC and CN field personnel indicated that room existed at all sites for the proposed equipment. The following cards were to be provided:

2	VME 68000 CPU Cards
1	Radio Card
1	Modem/Sync Detect Card
1 or 2	Vital Interface Cards (each card supports 4 polar or 2 bi-polar vital inputs)
2	Power Supplies (1 @ 13.6 VDC, 1 @ +5, +15, and -15 VDC)
1	Bus connect Cards — connects the two CPUs to the vital low-speed bus (similar to Microlok).

Table 1

Signal No.	Location	No. of Heads	Distance from Trans. (approx.)	Number of Trans.
242N	Silver	-	-	2
242S	"	-	-	2
263N	Stewartlown	1	11880	1
263S	"	1	11880	1
266N	"	1	8448	2
266S	"	1	8448	2
280	Speyside	1	10401	2
281N	"	1	8448	2
281S	"	1	8448	2
300	Int. Sig.	1	10401	1
301	"	1	13042	1
323	Mansewood	1	13402	2
324N	"	1	10401	2
324S	"	1	10401	2
343N	Milbase	1	10401	2
343S	"	1	10401	2
344	"	1	9821	2
361	Int. Sig.	1	9821	1
362	"	1	8500	1
363	El. Lock	0	TBD	2
377	Int. Sig.	1	8500	1
378	"	1	9082	1
395	Ash	1	9082	2
396N	"	1	9029	2
396S	"	1	9029	2
411N	Int. Sig.	1	9029	1
411S	"	1	9029	1
412N	"	1	9662	1
412S	"	1	9662	1
429N	Tansley	1	9662	2
429S	"	1	9662	2

The unit is equipped with EMI shielding, the front cover serving to complete the shield. Vital inputs will be equipped with lightning protection (varistors), but primary lightning protection comes from the lightning protection unit (LPU).

6.2.3.1 WIU Functions

(1) Signal Aspect Monitor

The WIU monitors all signals associated with a particular wayside location using the vital inputs. The WIU contains vital subsystems. The high impedance (on the order of 2K ohm) vital inputs will be bridged across the circuits leading to signal heads at the main terminal board. The vital input design is the same as that used in Microlok. The circuits are monitored on the inside terminal point. One vital input was to be required per aspect. The WIU interface uses standard, railway accepted circuits/components to ensure that both the vitality and reliability of the existing wayside signalling circuits are not affected. CN Signal Engineering personnel reviewed and approved the design of the interface.

(2) ATCS Communications Hardware

The ATCS communications functions are integrated into the WIU. As with the LOBC, available radio technology is used. The WIU is equipped with a single channel UHF (450 MHz area) half-duplex transceiver. GFSK transmission at 4800 bps is used. It is estimated that the transmit power required is approximately 2 watts. An entrance for the coaxial cable will have to be provided.

(3) Diagnostic MMI

The WIU is not equipped with a permanent MMI. An RS-232 port is provided to access diagnostics, etc.

6.2.4 LPU Functions

The LPU provides high voltage lightning protection on the signal circuits. The LPU is located between the WIU and the main terminal board. The LPU will be mounted as close to the main terminal board as possible to maximize lightning protection. The WIU card cage can be rack mounted or mounted using brackets at some intermediate signal sites.

6.2.5 Battery Surge Protector

A standard US&S battery surge protector is to be provided between the 12VDC signal battery and the WIU.

6.3 REVISED LOCOMOTIVE HARDWARE DESIGN

6.3.1 General

The LOBC was changed such that it is non-vital. However, the LOBC does contain hardware designed for vital operation. The software (safety platform et al.) to implement use of the safety platform was not written.

There were some small changes to the unit's outside dimensions. The unit now measures approximately 16"Hx27"Wx13"D.

There were no changes in the quantity or function of the cards.

6.3.2 Interface Design

There was no change.

6.3.3 MMI

There was no change to the MMI.

6.4 REVISED WAYSIDE HARDWARE

6.4.1 General

The hardware configuration of the WIU itself was changed. These changes are explained in the following sections.

6.4.2 Transponder Locations

The transponders were located and installed as planned.

6.4.3 WIU

The WIU was changed from a dual CPU system to a single CPU on the VLS bus. The following cards were provided:

1	80188 CPU Card (from RMS Industrial Controls)
1	Radio Card
1	Modem/Sync Detect Card
1, 2, or 3	Vital Interface Cards (each card supports 4 polar or 2 bi-polar vital inputs).
2	Power Supplies (1 @ 13.6 VDC, 1 @ +5, +15, and -15 VDC)

The mechanical packaging remained the same.

6.4.3.1 WIU Functions

(1) Signal Aspect Monitor

There is a change in the way the signal lights are encoded. Each signal head requires two vital inputs to encode the three possible aspects.

(2) ATCS Communications Hardware

No change.

(3) Diagnostic MMI

A VT100-compatible terminal is required to enter the time and date in order for the WIU to begin functioning. After the time and date have been entered the WIU will "dump" out any activity.

6.4.4 LPU Functions

No change.

6.4.5 Battery Surge Protector

No change

7. DETAILED DESCRIPTION - SOFTWARE

The signal enforcement software is divided into four logical groups based on functionality. These groups are: the safety platform, the communication system, the WIU application, and the LOBC application.

The logical groups are merged in different combinations to form desired systems. For example: to build an operating wayside system the software required was the WIU application, the communication system, and the safety platform. Similarly to build an operating on-board system the software required was the LOBC application, the communication system, and the safety platform.

7.1 ORIGINAL DESIGN DESCRIPTION

7.1.1 Communication Software

The proposed communication system was based on a reduced ATCS RF model with modifications to handle the missing base stations.

The Application layer (layer 7) and Presentation layer (layer 6) were eliminated, as the applications (WIU and LOBC) were to work with defined ATCS constructs. Hence, there was no need to format the data. The messages were to be formatted in the application software and the reverse process was to be done at the receiving application.

The Session layer is a subset of the ATCS defined session layer. It has a limited number of open sessions (maximum 15). This avoids using an indefinite amount of memory. The session layer also does not support the master-slave sessions at this time.

The Transport layer is significantly reduced from the model pro-posed in the ATCS specification. All messages are restricted in size to a single packet, thus eliminating the requirement that messages be disassembled and re-assembled. There is no acknowledgement for received messages, thus eliminating the message re-try mechanism. The vital CRC generation for the message was to be installed.

The Network layer is substantially reduced because packet priority and acknowledgement are not implemented.

In the Datalink layer the monitoring of busy bits is eliminated. However, the busy bits are inserted at the transmitter. The transmitter is always enabled and the queues are not prioritized.

The communication link in addition to handling the RF link is also to handle the printer, the MMI (PTxD), and the tag reader. As none of these followed the ATCS specification, the layer of Transport through Datalink are simplified.

7.1.2 Safety Platform

The safety platform was intended to give the hardware and software engineers a vital system base upon which to build specific products. The hardware and software of the safety system were intended to be fixed with defined points for controlled expansion.

The discrete I/O (excluding communications) provided by a low-speed bus was patterned off of U.S.&S.'s Microlok bus and loosely based upon Siemen's SMP. This bus provides for feedback of board type and board position to facilitate system checking by the software. The CPUs utilize the standard VME bus. VME is a multi-processor bus, thus allowing processing power to be increased when required.

The technical challenge in the overall system is the software to drive the dual CPUs and handle the sharing of the resources. This software was to become the operating system. This operating system was to run on and between the CPUs concurrently. The resulting system was to allow programmers, for vital processes, not to have to worry about multiple CPUs.

A further refinement to the original safety platform design was the use of a different compiler for each CPU, thus reducing the possibility of a compiler error.

7.1.3 WIU

The WIU software constantly monitors the vital inputs to determine the state of the signals. This information will be broadcast, at three-second intervals, 64 times upon the receipt of the wake-up call.

Diagnostic information will be dumped to one of the three spare serial ports with a date from the battery backed up clock.

7.1.4 LOBC

The LOBC software tasks include location determination, braking curve calculations, wayside interrogation, and brake application logic. The LOBC software also consists of a track data base based upon the structures outlined for ATCS. The track data base describes the section of the track under test.

7.2 REVISED SOFTWARE

7.2.1 Communication System

The implemented system only slightly deviates from the proposed system. The Application and Presentation layers were implemented by procedures as opposed to separate tasks.

The Session layer in the WIU was limited to two (2) active sessions. This was the number required to support the RF link. The LOBC has 15 sessions.

The Transport layer vital CRC was replaced with CRC_{16}.

The Network and Datalink layers were unchanged.

The WIU free serial port was not accessed through the communication system. The application software deposited/fetched directly to/from the transmit/receive queues of the serial port. The LOBC will retain the feature of communicating through the communication session.

7.2.2 Safety Platform

The safety platform was not implemented.

7.2.3 WIU

The dual 68000 VME-VLS system was dropped in favour of a single 80188 CPU.

7.2.4 LOBC

The LOBC software was not ported to the target hardware. It was developed and tested on a PC-AT compatible under MS-DOS. The following were changed: no safety platform, braking curve simplified, and the RF link. The AT did monitor a serial line for the tag reader. The tag reader was simulated by a PC clone that contained the list of tags as they would be encountered on the actual route. The AT communicated with an actual MMI. The AT also calculated speed from an input driven by a signal generator.

A PC-AT could not be used to drive the RF link due to its limiting interrupt structure. The AT's interrupt structure depends upon software to determine the cause of an interrupt. This determination is performed in software and adds a significant amount of overhead to each interrupt, thus slowing down the AT's response. The planned target hardware had the capability of bypassing this step and thus was capable of operating at 4800 baud.

8. DEVELOPMENT STATUS

The project was concluded before the system was fully developed and installed at the proposed test site. This section summarizes the entire development effort to date.

8.1 SYSTEM DESIGN

The original system concept has been defined down to a very detailed level of definition. In the process of this effort, it is felt that all key areas requiring study and analysis (from communications through signal systems) have been investigated and that the current system definition does include any unresolved issues. The final system design as presented represents a feasible method of providing enforcement in signalled territory.

8.2 SUBSYSTEM STATUS

	Hardware	Software	Testing
MMI	Complete	Complete	Subsystem Level
WIU	Complete	Complete	Subsystem Level
LOBC	Complete	Incomplete	none

8.3 PACKAGING

The packaging effort was completed for both WIU and LOBC with the exception of the mounting arrangement for the LPU in the intermediate sites.

8.4 HARDWARE

All cards have been designed and tested.

Component	Implementation
Vital Backplane	Printed Circuit Board
Vital Input	Printed Circuit Board
Radio Interface	Printed Circuit Board
ATCS Modem/Sync	Printed Circuit Board
Vital Brake Control	Wire Wrapped Board
Locomotive Interface	Wire Wrapped Board
VLS-VME Interface	Printed Circuit Board
VME-VLS Interface	Wire Wrapped Board

8.5 SOFTWARE

Component	Status
Communication Software	Completed and fully tested on 80188 and 68000 CPUs
Safety Platform	Preliminary system design completed
WIU Application Software	Complete and tested
LOBC Application Software	Prototyped on a PC-AT

9. PROJECT CONTINUATION

The complexity of the final software and hardware was under-estimated when this project was initiated. This occurred because the hardware and software requirements of an ATCS-like system were not fully appreciated at the time the project was initiated. Now the situation is markedly different, the risk in completing the project is minimal:

(1) Equipment designs fully reflect system hardware and software requirements.

(2) All hardware and packaging has been designed, implemented and tested.

(3) The WIU software, hardware, and packaging has been fully implemented, the unit is ready for field trials.

(4) The ATCS communications subsystem software and hardware has been implemented and lab tested. (Data transfer via the RF data link has been achieved between a WIU and a simulated LOBC.)

(5) LOBC software has been developed and is operational on a PC-AT platform. The remaining effort is to port the software to a VME environment.

(6) Hardware and software designs are completed and fully documented.

The above factors indicate that it is feasible for another qualified supplier to continue and complete the project.

10. CONCLUSIONS

The radio-based signal enforcement system represents a viable low-cost alternative to ATCS as a means of increasing rail safety in signalled territory.

The bulk of the development effort has been completed. The completion effort is of limited scope and low risk. The documentation effort will allow another supplier to continue system development.